diseases mentioned being due to uncorrected age and locality factors, the *net* correlations after correction has been made for these factors, *are actually higher than were the gross, uncorrected correlations.* The net correlation of the pulmonary tuberculosis death rate with epidemicity index is the highest of the three. It has a value about 9 times its probable error. The chances are literally billions to 1 against this correlation being due to accident or chance. We may conclude that the most significant factor yet discovered in causing the observed wide variation amongst these 39 American cities in respect of the explosiveness of the outbreak of epidemic influenza mortality in the autumn of 1918 was the relative normal liability of the inhabitants of the several cities to die of one or another of the three great causes of death which primarily result from a functional breakdown of one of the three fundamental organ systems of the animal body, the lungs, the heart, and the kidneys.

VII. Summary.

In this first study the weekly mortality statistics of the influenza epidemic beginning in the autumn of 1918 have been analyzed in a preliminary way for some 39 large American cities. It has been shown in the first instance that there was an extraordinary degree of variation amongst the several cities in this group of cities in respect of the relative degree of explosiveness of the outbreak of epidemic mortality. The first problem confronting the student of the epidemic was the analysis of this variation, to find, if possible, primary factors concerned in its causation. Such an analysis, by the method of multiple correlation, appears to demonstrate that an important factor so far found in causing the observed wide variation amongst these 39 American cities in respect of the explosiveness of the outbreak of epidemic influenza mortality in the autumn of 1918 was the magnitude of the normal death rates observed in the same communities, particularly those death rates from pulmonary tuberculosis, diseases of the heart and of the kidneys.

OBSERVATIONS ON THE FOOD OF ANOPHELES LARVÆ.

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Obviously, food is an important factor in determining the abundance and distribution of Anopheles larvæ, and for this reason it is a factor to be considered in connection with Anopheles eradication. The following results are from experiments and observations made in an attempt to ascertain the essential food requirements of Anopheles larvæ. At first it was intended that the analysis extend to the particular species of animals and plants contributing to the larval food,

with a view toward evolving an indirect method of Anopheles control through diminution of the food supply; but it was soon evident that this would be very difficult to accomplish owing to the wide range of suitable food materials. The observations are, therefore, recorded mainly for the additional light they throw on anopheline characteristics. They deal primarily with the general types of food, the effects of chemical contamination, water pollution, active decomposition of food materials, and related subjects.

The experiments were conducted during the summer and autumn of 1918 in Alabama (near Montgomery) and in Florida (near Lakeland). They deal with the three common Atlantic coast species of Anopheles: *A. punctipennis* Say, *A. quadrimaculatus* Say, and *A. crucians* Wied., especially the latter two. Some of the observations herein recorded were noted briefly in a previous paper, "Anopheles Crucians: Habits of Larvæ and Adults" (Public Health Reports, vol. 33, pp. 2156–2169).

So far as the writer is aware relatively little has been published respecting the larval food of American Anopheles. Howard, Dyar, and Knab (1912, vol. 1, p. 230) observe concerning Anopheles larvæ in general:

"The larva feeds upon everything that floats. It is especially often found in stagnant water on which there is more or less of an algal scum; therefore, a very frequent food consists of algal spores, and the color of the larvæ is influenced more or less by the character of the food, green algæ making it green. Daniels, in his African investigations, found that the contents of the intestines of the larvæ are mainly vegetable matter, in some cases entirely so: 'Occasionally limbs of minute insects or crustaceans are found, as well as the scales of mosquitoes or other insects. On watching them feeding, it is seen that all minute particles are drawn to the mouth, but many of them are rejected. This rejection is somewhat arbitrary, as a particle at first rejected is often subsequently swallowed. Amongst the bodies seen to be swallowed I have seen living minute crustaceans and young larvæ, both of Anopheles and Culices, but, as a rule, living animal bodies either escape or are rejected.' Christophers and Stephens state that in their observations in Sierra Leone the food of the Anopheles larvæ seemed to be a unicellular organism. James and Liston state that the food of Anopheles larvæ consists chiefly of minute water animals which abound among algæ and other plants. They believe that the larvæ can not subsist upon a vegetable diet alone and that the duration of the larval stage depends chiefly upon the supply of animal food. When this is small in proportion to the number of larvæ, they state, the stronger larvæ kill and eat the weaker. The cause for the discrepancies in these observations undoubtedly lies, at least in part,

in the fact that different species were under observation. Thus we have found that the tree-hole-inhabiting larvæ of our *Caelodiazesis barberi* are very largely predaceous and prey upon other *culicid* larvæ associated with them. The species inhabiting *bromeliads* (pineapple family of plants) have similar habits, as has been recorded for *Anopheles cruzii* by Peryassu."

Similarly in Volume IV of the same work (1917, p. 965) they note that "the larvæ of Anopheles generally occur in water containing algæ, upon which they feed; but James and Liston state that they can not subsist upon a vegetable diet alone, but feed upon minute water animals. Some of the species are, in part, at least, predaceous upon other mosquito larvæ." Thus no significant additions to the subject are recorded by Howard, Dyar, and Knab between 1912 and 1917. Miss Cora A. Smith (Psyche, 1914, Vol. XXI, pp. 1–19) notes certain observations on food made in connection with a study of the development of *Anopheles punctipennis*, and doubtless other similar observations have been recorded that have not come to the attention of the writer, but apparently no especial study of the subject has been made.

The observations of Miss Smith may be summarized as indicating that *punctipennis* larvæ feed on filaments of Spirogyra, Zygnema, and Mougeotia and on particles of Cladophora and Lemna and perhaps Polygonum. They were observed to brush off and devour Vorticellæ, diatoms, etc., that adhered to their own bodies and to ingest other small organisms that happened to be drawn into the mouth. Miss Smith also noted finding robust larvæ in a small pool, the bottom of which was covered with dead leaves, but in which the water was clear and without any visible algæ or other plants. This latter observation is of particular interest in connection with some of the experimental evidence given below, indicating that the larvæ may develop prolifically on dead, disintegrated plant tissue.

FIELD OBSERVATIONS.

General observations.—Certain characteristics of Anopheles, in regard to choice of breeding places, are well known, as, for instance, the usual preference for natural waters instead of artificial containers, the general aversion for sewage-polluted waters, and the usual avoidance of salt water (sea water). The various species differ somewhat in these respects, but the three under consideration show the above characteristics in a definite manner, although *crucians* exhibits less aversion for salt water than do the other two. Each of the three characteristics presents an interesting problem to the student of mosquitoes. The avoidance of artificial containers is probably due to at least two things—an unsuitable food supply, and insufficient aeration.

It is well known that Anopheles larvæ kept in small containers will usually die even in the presence of suitable food and under conditions that present no obstacles to the propagation of Culex and other mosquitoes. Artificial aeration will often remedy this difficulty, and hence it is assumed that a lack of oxygen or an excess of CO_2 is the responsible factor. In larger containers aeration is less important and absence of suitable food is probably more often the deciding factor, although it seems not unlikely, from results noted below, that an undue concentration of food with attendant excess of decomposition may be an important element in restricting the distribution in such receptacles as eaves and troughs that become filled with leaves, grass or rubbish. It would appear that the usual absence of Anopheles in artificial containers is due to the restricted range of adaptability of larvæ of this genus, coupled with the widely diverse conditions found in artificial containers. On this view the number of records of Anopheles breeding in artificial containers would be an index of the frequency with which conditions such as food and aeration happened to be suitable in these containers.

The absence of Anopheles in sewage-polluted waters appears to be merely an extreme example of the general avoidance of polluted waters by members of this genus (at least the three considered here). Other examples are to be found in natural waters in case these are confined (i. e., in pools or puddles) and are full of decomposing vegetable or animal matter. Barnyard or pasture puddles containing considerable amounts of manure also furnish illustrations of Anopheles' avoidance of polluted water.

The general aversion for salt water, or water otherwise impregnated with chemicals, would seem to be due to a physiological reaction, and furnishes another illustration of the limited range of adaptability of the species here considered. It is to be noted, however, that the individual species are by no means alike in this respect, *crucians*, especially, being able to adapt itself to a considerable range of alteration in chemical content of the water. This feature has been dealt with in greater detail by the writer in the paper previously referred to.

Special observations.—Detailed individual observations of Anopheles larvæ feeding on certain kinds of organisms have been made by numerous observers. In most cases these relate to the larvæ feeding on green algæ (filamentous or unicellular) and other water plants. Howard, Dyar, and Knab (loc. cit.), however, cite James and Liston as claiming that the food consists mainly of water animals and that a vegetable diet will not suffice. The latter authors even maintain that in the absence of sufficient animal food of this sort the larvæ kill and eat each other. Their statements are probably intended to apply only to the particular species of Anopheles with which they dealt and may,

therefore, be justifiable, but it is practically certain that they do not apply to the three American species considered here. That *punctipennis, quadrimaculatus* and *crucians* will develop on a diet mainly, if not entirely, vegetable is made probable by the records of several observers (e. g., Smith, 1914, loc. cit.) corroborated by the writer, and has been demonstrated experimentally by the writer (vide infra). The field observations indicate that most, if not all, of the green algæ are suitable for food, the plants being ingested entire if small enough, and in the form of filaments or particles if large. The writer has observed *punctipennis* larvæ in puddles in which the water was green with a profusion of unicellular and colonial green algæ that formed the bulk of the larval food.

But it is also probable that an animal diet is equally suitable for Anopheles development. The writer has observed one case in which Anopheles larvæ (*quadrimaculatus* or *crucians* or both) flourished in water containing little, if any, available food other than green rotifers. This water was swarming with the rotifers, of which there were apparently two species of very different sizes. It was observed that the larvæ fed mainly on the smaller, darker form—presumably because the larger was too large to be swallowed. Examinations of the stomachs of some of these larvæ revealed nothing but the remains of the rotifers. A score or more of the larvæ were brought into the laboratory and kept in a pan of the water in which they were taken. These developed rapidly and hatched into vigorous adults. So far as could be determined, their food, both in the pond and after being taken into the laboratory, was almost exclusively green rotifers.

It would appear, then, that the natural food of the Anopheles larvæ includes a wide range of aquatic organisms, and that, so far as the species under consideration are concerned, the organisms may be either animals or plants.

In certain cases, however, prolific Anopheles breeding has been observed in waters containing very few living organisms of any kind small enough to furnish food. One case that may be of this sort is mentioned by Miss Smith (loc. cit.). Another was observed by the writer (loc. cit.). The latter case was that of a large swamp contaminated with chemicals. Centrifuged samples of water from this swamp gave a residue composed almost entirely of minute particles of disintegrated tissue. Since there were no fish and few other aquatic animals except mosquito larvæ in this water, and since there was an abundance of dead leaves, etc., covering the bottom of the swamp, it is practically certain that the disintegrated tissue was mainly plant tissue. If so, the diet of the larvæ was almost exclusively vegetable. In this instance only one species of Anopheles was involved—*A. crucians.*

EXPERIMENTS.

The field observations noted above suggested the following experiments designed to ascertain the suitability of certain food materials and to determine the effects of sterility as contrasted with active decomposition in the food.

Experiment 1. (Montgomery, Ala.)—On July 29, 1918, 13 very small, newly hatched Anopheles larvæ were taken from a ditch and put into a pan of boiled water from the same ditch. Each day thereafter until the experiment was completed the water in the pan was replaced with newly boiled water from the ditch. In this way a culture was secured that closely resembled the natural environment of the larvæ, except that it was sterile and afforded no living food. The larvæ in this culture flourished and grew rapidly. Four of them died, probably from injury, but the remaining nine pupated and all hatched within 16 days into vigorous adults of *A. punctipennis.*

In two control cultures of larvæ taken from the same place at the same time and kept under identical conditions, except that the water was not boiled, all but three of the larvæ died. These three pupated and hatched.

Experiment 2.—On August 13 a similar experiment was begun with small larvæ of *A. crucians* from a swamp. The larvæ were kept in freshly boiled water, which was changed daily. They likewise grew rapidly and pupated. The experiment had to be terminated on August 28, when only one adult had appeared; but it was evident that the food and environment in the culture were well suited to the needs of this species.

Experiment 3.—On August 12 several very small larvæ of *A. crucians* were put in a culture consisting of dead leaves, dried and ground, added to essentially sterile water from a deep well. This was likewise changed daily. Again the larvæ grew vigorously, began pupating on August 22, and continued to pupate until the culture was discarded on August 28.

Experiment 4 (Lakeland, Fla.).—On November 12 a mass of decaying vegetation (leaves, grass, etc.) was thoroughly boiled and samples were added to two pans of city tap water—from deep wells. In one pan (a) the concentration was approximately twice that in the other (b). Between 25 and 30 very small larvæ were added to (a) and half that number to (b). In both of these pans the larvæ grew rapidly and matured. The food was not renewed daily, as in the previous experiments, but was renewed once—on November 20. However, no protozoal or bacterial action was observed in the culture and microscopic examination of the stomach contents of a large larva from (a) on November 18 revealed only disintegrated plant tissue. The larvæ in these two cultures pupated and hatched approximately as follows:

CULTURE (a).

Pupated.		Hatched.			Pupated.		Hatched.		
Date.	Number.	Date.	Number.	Species.	Date.	Number.	Date.	Number.	Species.
Nov. 20	2	Nov. 24	2	Crucians.	Nov. 27	4	Nov. 29	5	Crucians.
21	2	25	4	Do.	28	2	Dec. 2	1	Do.
22	2	26	1	Do.	29	1	4	1	Do.
24	5	27	2	Do.	30	2	6	1	Do.
26	2	28	5	Do.					

CULTURE (b).

Pupated.		Hatched.			Pupated.		Hatched.		
Date.	Number.	Date.	Number.	Species.	Date.	Number.	Date.	Number.	Species.
Nov. 24	1	Nov. 26	1	Quadrimaculatus.	Dec. 3	2	Dec. 6	1	Crucians.
25	4	28	4	Crucians.		......	7	1	Do.
27	1	29	1	Do.					

It was observed during the course of this experiment that the larvæ in culture (a) grew more rapidly and appeared more vigorous than those in (b), presumably because of the greater concentration of food in (a).

Experiment 5.—This experiment differed from the preceding mainly in the substitution of one particular species of plant for the heterogeneous mixture used as food in Experiment 4. A mass of Spirogyra was taken from relatively clean water in a lake, washed thoroughly to remove all but traces of any animal matter that might be adhering, and then baked and ground. A portion of this was added to tap water in a pan and from 15 to 20 very small Anopheles larvæ were introduced on November 19. These grew vigorously, and pupated and hatched approximately as follows:

Pupated.		Hatched.			Pupated.		Hatched.		
Date.	Number.	Date.	Number.	Species.	Date.	Number.	Date.	Number.	Species.
Nov. 27	1	Dec. 2	4	Crucians.	Nov. 30	3	....	......	
28	3	3	3	Do.	Dec. 1	3	....	......	
29	4	5	5	Do.	2	2	....	......	

Experiment 6.—A similar experiment was performed at the same time, using the roots of a local "water hyacinth" (Eichornia) washed, baked, and ground. Again the larvæ grew vigorously to maturity. The culture was discarded before hatching was completed, but two pupæ were transferred to a hatching bottle and retained. They proved to be *quadrimaculatus.*

Experiment 7 (Montgomery, Ala.).—On August 8 several small larvæ were put into a culture of Spirogyra similar to that in Experi-

ment 5, except that in this case the Spirogyra was dried, ground, and then boiled, and the larvæ were transferred daily to a freshly prepared medium, insuring a practically sterile culture at all times. The same rapid growth and general vigor were observed in this experiment. The larvæ pupated from August 14 to 22, and began hatching on August 16. Four specimens of *quadrimaculatus*, 2 of *punctipennis*, and 2 of *crucians* were obtained before the culture was discarded on August 24.

Experiment 8.—This experiment differed from the last in the substitution of uncooked Chara for cooked Spirogyra. Apparently Chara is less suitable as food for the larvæ, for they did not thrive, and only one specimen hatched—*A. quadrimaculatus.*

DISCUSSION.

It is evident from these experiments that the diet of Anopheles larvæ may be either heterogeneous or homogeneous—consisting of mixed animal and vegetable materials, of mixed vegetable materials, or of individual species of plants or animals. And, apparently, it makes little difference whether the food is composed of living organisms or their dead remains. No effort was made to ascertain how many types of animals and plants furnish suitable food materials, since the range is evidently great. Only one of the types tested gave indications of being unsuited. This was Chara, and even it provided adequate food for the development of some larvæ to maturity.[1]

Of greater interest, perhaps, is the evidence regarding the effect of pollution or decomposition on the larval development. In most of the above experiments the culture media in which the Anopheles larvæ developed were essentially sterile, i. e., there were practically no protozoa present, and there was a negligible amount of bacterial action. The cultures were kept in shallow, granite pans, 10 to 12 inches in diameter and 3 inches deep, and it was found that no artificial aeration was necessary. In other cases, when cultures containing relatively large amounts of decomposing vegetation were brought into the laboratory and kept without sterilization or aeration, the larvæ usually lost vigor and died in a few days.[2]

Thus the experimental evidence leaves little doubt as to the detrimental effects of pollution or decomposition. Whether the injurious effects of decomposition are due directly to bacterial or protozoal action on the larvæ themselves or indirectly to an excess of CO_2 or other gases resulting from the decomposition, is not certain. The

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[1] It should be noted that Miss Smith (Psyche., Vol. XXI, p. 3) cites the feeding of *punctipennis* larvæ among the filaments of fruiting Chara.

[2] See Carter, Le Prince, and Griffitts, Public Health Bulletin No. 79, pp. 15, 22-23. These authors note the deleterious effects of decaying grass both in natural waters—i. e., pools—and in collecting pails containing larvæ.

latter seems more probable, however, since the detrimental effects may often be prevented by aeration.

Contrary to popular belief, then, it appears that the purer and more sterile the waters may be, so long as they contain sufficient food, the more suitable they are for Anopheles breeding. This would seem to account for the fact that rain-water puddles and seepage pools frequently permit much more prolific breeding than near-by, stagnant waters. It also serves to emphasize the danger of doing more harm than good by cleaning the refuse from such places as sloughs and stagnant puddles, unless adequate provision is made for subsequent drainage, oiling, fish control, or some other method of mosquito eradication.

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LOCATION OF DETENTION HOSPITALS.

COURT DECIDES THAT BOARD OF HEALTH CAN NOT LOCATE AND MAINTAIN A DETENTION HOSPITAL IN A THICKLY SETTLED RESIDENTIAL SECTION.

A board of health can not establish and maintain a detention hospital for the treatment of communicable diseases in a thickly settled residential district. This is the decision in a case [1] decided by the Supreme Court of Michigan.

Suit was brought to restrain the maintenance of a detention hospital in a residential district by the board of health of the city of Lansing. The city charter provided as follows:

> The said board of health shall have power, and it shall be its duty, to take such measures as shall be deemed effectual to prevent the entrance of pestilential disease into the city, * * * to establish, maintain, and regulate a pesthouse or hospital at some place within the city or not exceeding 3 miles beyond its bounds.

The court in granting the injunction said:

> We conclude that the provisions of the charter under consideration do not vest in the defendant board of health the power to locate a pesthouse in a thickly settled residential district, where, by reason of its location, it would be a nuisance, and where its permanent maintenance would work continuing damage to adjoining and near-by property and would result in the destruction of the home in its comfort and well-being; and that the discretion lodged in the board is a discretion to be exercised by it in determining between different lawful locations.

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[1] Birchard et al. v. Board of Health of City of Lansing et al., 169 N. W., 901.